Environmental Valuation Using Cross-City Hedonic Methods [1]

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1. Introduction

In the 21st century capitalist urban economy, workers are footloose. While coal miners and lumberjacks seek out areas rich with the natural resources they extract, and strawberry farmers need ample access to water, most workers now seek out locations because they want to live there. Given that a majority of the world's people now live in cities, those cities that are perceived to be "consumer cities" will thrive while those that have a low quality of life will suffer from declining home prices, outflows of the skilled and a declining tax base (Glaeser, Kolko and Saiz 2001, Florida 2003). Which cities "have it" and which cities "don't"? For cities with low quality of life, is there anything they can do to make a comeback?

While people differ with respect to their priorities over non-market spatial attributes such as crime, pollution and climate, few would disagree that a high quality of life city will feature low crime levels, short commutes, good public schools, clean air and water and temperate climate, recreation opportunities and a variety of shopping and cultural opportunities. Given this list of city attributes, how should a Mayor or a business CEO seeking out a high quality of life city for locating his business judge which of these are most highly valued by people (see Gabriel and Rosenthal 2004)? Popular magazine surveys of the "Best Cities to Live" simply make up the index weights for aggregating different data categories into a single quality index.

Twenty five years ago, Sherwin Rosen proposed an alternative revealed preference method for recovering how much households pay for non-market local public goods (Rosen 1974, 1979). If households correctly perceive the differences in

environmental quality across areas and if migration costs are low then higher quality differentiated products will sell for a premium. Environmental hedonic researchers have attempted to decompose housing price differentials into their pieces. All else equal, how much lower would one's wage be a city with low crime relative to high crime? How much higher would one's rent be for the same physical structure if the structure is located in a temperate climate rather than in a hot, humid climate? Hedonics recovers implicit prices that can be used to form indices and to compare the marginal consumer's valuation of different local public goods. For a review of many of the issues that arise in using the hedonic approach to value urban amenities see Gyourko, Kahn and Tracy (1999).

Using hedonic methods, numerous cross-city studies have priced all sorts of non-market environmental attributes ranging from climate, to air pollution, to earthquake risk. Cross-city hedonics is a mature literature. To avoid the fate of being consigned to specialty field journals, hedonic researchers must focus on core research questions that interest researchers outside of this specific sub-field. This chapter tries to provide some guidance on this issue by focusing on some of the exciting recent developments in this field and by identifying potentially rewarding future avenues for hedonic research. An investigation of the state of the art of hedonic research matters because this technique remains one of the major tools used by environmental and real estate economists to value non-market goods. It represents a revealed preference alternative to contingent valuation.

2. Estimating Cross-City Hedonic Pricing Functions

Imagine an economy where everyone has the same preferences defined over just two goods called pizza and climate. Climate is exogenously supplied to different cities

and cities only differ along this dimension. Some cities have warm climates and other cities have cool climates. Assume that all workers have identical human capital levels. If migration costs across cities are zero, then in equilibrium these workers must be indifferent between where they live. Thus, if the representative consumer prefers city A's climate to city B's climate, then city B's wages and rents must adjust such that disposable income in city B is higher than in city A

to compensate the worker for living in the worse climate. In this simple case where everyone is identical, the equilibrium differences in annual wage income minus rents across cities would sketch out this representative consumer's indifference curve. The marginal rate of substitution at any point could be recovered from a hedonic regression of the form: (wage income –rent) = f(climate) + U , where f() is a flexible polynomial of climate. Through differentiation, this hedonic equation immediately provides the compensating differential for consuming extra climate. The first stage hedonic gradient estimates the implicit prices of capitalized non-market goods, in this case climate.

There is no reason why everybody's preferences for climate are identical. If the population is heterogeneous and if f() is not a linear function, then OLS estimates of this hedonic yields the consumer's non-linear budget constraint. Suppose we observe a household choose a climate level of 75 and a pizza level of a 150 when if she chose a climate level of 76 then the hedonic estimate of equation (1) predicts that her pizza level would have been 144. We immediately learn that at the margin that this consumer valued the 76^{th} unit of climate at less than 6 pieces of pizza. Why? From simple revealed preference. When offered the choice, she said no and thus we now know the upper-bound of what she is willing to pay (measured in pizza) for a marginal increase in

climate. The general point here is that when the population has heterogeneous tastes for non-market goods, by estimating the non-linear hedonic gradient and knowing what point a consumer chose on this gradient, the researcher can bound willingness to pay for the attribute (Rosen 2002).

Before leaving this simple economy, it is worthwhile to point out two additional issues. First, consider the incidence of amenity improvements in an open economy. Let city B experience climate change that makes it weather identical to city A. As the climate improves in city B, there is no reason for why there should be an equilibrium compensating differential for living there and thus disposable income would fall at that location. In an open economy where people can freely migrate across cities, improvements in one area will not offer a "free lunch" to its residents. Improving areas will experience a labor influx that will drive down wages and raise rents. A recent example of this point is the recent rise in home prices in Harlem in New York City. As crime has sharply declined in major cities, poor people who live in high crime areas enjoy a higher quality of life but are likely to be priced out of the community as entrants bid up rents (Levitt 2004).

One other issue merits attention. Implicit in the hedonic literature is the assumption that prices have adjusted such that supply equals demand in each local housing market. Consider New York City rent control and assume the draconian case where all housing units are apartments and are rent controlled such that price is less than the market price and demand exceeds supply. The naïve hedonic researcher would observe low rental prices in New York City and would estimate that the attributes that the city is endowed with such as museums and culture must be "bads" because rents are low.

In recent work Glaeser, Gyourko and Saks (2003) have documented that major Californian cities and major Northeast cities such as New York City have regulatory taxes such that the price of housing is greater than the marginal cost of constructing it. They identify certain barriers to entry in housing supply, their regulatory tax. The implication of their finding for hedonic researchers is the opposite of the rent control example given above. Prices in these regulatory tax cities are higher than they would have been in the absence of the supply constraint. The naïve cross-city hedonic researcher would conclude that consumers highly value the amenities that these cities are endowed with. While this is true for the marginal consumer, the key counter-factual is what would the hedonic price gradient have been if there was no regulatory tax in any city. In the face of the regulatory tax, the supply of housing is constrained and in these markets the gains to trade between home buyers and developers are not exhausted. An interesting identification problem arises if Glaeser, Gyourko and Saks (2003) are correct that a certain subset of coastal cities enact hard to quantify regulatory taxes. When we see high prices for real estate in coastal cities, is this due to perfect competition pricing out their intrinsic high quality of life and/or regulatory barriers that limit new construction?

3. The Supply of Local Public Goods

Many hedonic studies implicitly assume that the set of city specific local public goods are like climate in that they are exogenously supplied. Yet many local attributes such as crime, and school quality are determined by urban government's bundle of taxes and services. Cross-city studies such as Gyourko and Tracy (1991) and Welch, Carruthers and Waldorf (2004) have examined the capitalization of government services

per tax dollar collected. An interesting issue is whether a dollar of government expenditure on education, fire protection, housing and community, libraries, natural resources, parks, police protection, roadways, sewers, trash collection have equal effects on home prices. Suppose this research finds that expenditure on fire protection raises home prices more than expenditure on libraries. Why hasn't the typical mayor then re-allocated spending away from libraries and towards fire protection? One political economy explanation would be that the mayor is a longtime incumbent and has a monopoly over local politics and does not feel political pressure to address his constituents needs. An alternative explanation is that a sleepy local media is not providing sufficient oversight to inform the populace on what their leaders are doing.

Local government can increase the supply of local public goods through effective zoning regulation. The Urban Growth Boundary in Portland is pointed to as an example of how government regulation has mitigated sprawl by focusing on infill development (Phillips and Goodstein 2000). An intended consequence of zoning and land use controls is to mitigate negative externalities. An unintended consequence of such regulation is to raise the price of existing homes as this regulation acts as a barrier to entry (Katz and Rosen 1981, 1987 and Glaeser, Gyourko and Sachs 2003).

Government is not the only provider of local public goods that differ across cities. Whether they intend to or not, the highly skilled provide local public goods. All else equal, those who live in high human capital cities earn higher wages and pay higher rents (Rauch 1991, Moretti 2005). Building on the human capital literature in macro economics of Lucas (1988), a number of urban economists have documented the urban growth benefits of living in highly educated cities (Glaeser et. al. 1995). While this

literature has emphasized the learning and idea transfer from interacting with the highly skilled, quality of life is also likely to rise in cities that attract and retain the highly educated. This group forms the cultural elite to provide resources for museums and the arts, the financial muscle to support fancy restaurants and the political voice to lobby for historic preservation of older buildings and to block developments that may impinge urban environmental quality of life. This creates a type of multiplier effect. If a city can attract the highly educated, perhaps due to climate or lifestyle like a San Francisco, then this group in turn raises the "endogenous" local public good quality of the city and this in turn raises home prices. This logic chain explains why Rauch (1991) and others have found that all else equal, rents are higher in cities with higher levels of average human capital.

4. Measuring Expenditure on Urban Quality of Life

In any urban population, there is significant heterogeneity. The young and old may have very different preferences over local public goods. Immigrants may seek out cities with large numbers of people from their origin nation. In the presence of such heterogeneity, different households may be paying different amounts for local public goods expenditure. To keep things simple, assume that all workers have the same ability and that all housing structures are identical.[2] Cities differ with respect to their bundle of

[2] An additional complication that hedonic researchers face is the pricing of worker skills in different local labor markets. As discussed by Heckman and Scheinkman (1987) since workers cannot sell their brains to one local labor market and their muscle to another local labor market, there is little reason why there will be a "law of one price" for skills. Yet in the leading cross-city hedonic studies such as Blomquist, Berger and Hoehn (1988) and Gyourko and Tracy (1991), these researchers estimate hedonic regressions

local public goods. For household I in city j at time t, the hedonic home price gradient and wage gradient depend on a vector of l attributes bundled into each city.

$$\text{Home Price}_{ijt} = \Sigma_l \lambda_{lt} * (\text{Local Public Goods})_{jt} + U_{ijt} \quad (2)$$

$$\text{Annual Income}_{ijt} = \Sigma_l \vartheta_{lt} * (\text{Local Public Goods})_{jt} + U_{ijt} \quad (3)$$

Different types of families will be paying different amounts for local public goods. Gyourko and Tracy (1991) compared expenditure for a retired couple (no labor market capitalization), to a traditional one worker couple (one income and one home price). This demographic heterogeneity matters at a point in time for determining which groups are paying more for local public goods and, as I discuss below, it matters for constructing non-market local public goods price indices over time. As women's labor force participation has increased, more and more couples are two worker households. Costa and Kahn (2000) document the rise of power couples locating in big cities. While all households face the same cross-city hedonic pricing gradients, these power couples pay twice through the wage capitalization for public goods capitalized into the wage gradient.

5. Using Hedonics to Construct a Price Index for Non-Market Goods

Most hedonic research focuses on estimating a single hedonic regression to recover implicit prices for local public goods. But, suppose we could estimate the same hedonic specification every decade from 1960 to 2000. One payoff from estimating

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imposing a law of one price. For an empirical quality of life study that examines the spatial variation across cities in the returns to skill see Kahn (1995).

repeat cross-sectional hedonic regressions is to create a Laspeyres price index for non-market goods. The Boskin report on adjusting the Consumer Price Index briefly mentions incorporating environmental goods into price indices. The Consumer Price Index measures for *market goods* how much expenditure would be needed to buy the same real bundle in different years. Cragg and Kahn (1999) and Costa and Kahn (2003) show how to use cross-city hedonics to construct an analogous index for a leading non-market good climate.

Costa and Kahn (2003) estimate how the hedonic implicit price of climate has evolved from 1970 to 1999, using data from 1970, 1980, 1990, and 1999 for home prices and for wages in 1970, 1980, and 1990. For every year the results reported in Tables One and Two are based on regressions of the form,

$$house_{ij} = bX_i + gZ_j + u_{ij}$$

$$wage_{ij} = fV_{ij} + dZ_j + e_{ij}$$

where i indexes the housing unit or the individual, j indicates the metropolitan area, the dependent variables are the level of home prices multiplied by 7.5% (to impute an annual rental price for owners) and the level of the hourly wage, X is a vector of housing characteristics, V is a vector of worker characteristics, Z is a vector of climate controls (annual average January and July temperature, and annual average rainfall by metropolitan area, obtained from the National Oceanic Administration ftp://ftp.ncdc.noaa.gov/pub/data/ccd-data/), and u and e are error terms. The results presented in Tables One and Two are from a median censored regression (Powell 1984) in which standard errors are clustered by metropolitan area. The samples are described in the table notes.

In these hedonic results, Costa and Kahn (2003) simply include the climate variables as measures of metropolitan area non-market goods. Implicitly, this assumes that other non-market goods such as crime and pollution are uncorrelated with climate. One justification for such a parsimonious hedonic model is the inherent difficulty of collecting pollution and crime data by city/year.

Between 1970 and 1999, the average person increased his exposure to January and July temperature by 2.6 and 0.7 degrees respectively (see Cragg and Kahn 1999). Given the change in prices between 1970 and 1990, the average person has not substantially increased his climate expenditure. But, this average masks a large price increase for migrants to warm winter, cool summer climates (such as those offered in most of California). Based on the estimates reported in Tables One and Two, in 1970, a person would have to pay $1,288 (1990 dollars) in higher home prices to purchase San Francisco's climate over Chicago's climate. In 1990, this price differential increased by $6,259 (1990 dollars) to $7,547.

Future research might construct such non-market price indices for the retired, one worker households and two-worker households. Ongoing demographic changes would determine whether the "average" person is paying more for non-market environmental goods over time. If climate capitalization into wages is rising over time, then the growing numbers of retired people would be paying relatively less for climate than would two worker households. If senior citizens have different local public goods preferences than younger people, then composition shifts due to demographics will manifest themselves in repeat cross-sectional hedonic regressions. Future work might investigate whether the implicit prices of non-market goods that seniors demand is rising. If this is

the case, then their real income is lower than is commonly thought by researchers who abstract away from non-market local public goods.

6. Understanding the Sources of Hedonic Price Dynamics

Repeat cross-sectional hedonic estimation, through generating a price and quantity for each non-market attribute in each year, offers the possibility of making some headway on the second stage of the Rosen two step. Suppose that for some local public good we observe its hedonic implicit price rising over time and we calculate that the quantity of consumption has also increased. Simple supply and demand logic would suggest that prices and quantities can both only rise if the underlying demand for the good in question has increased.

Hedonic research should not be satisfied to simply document implicit price dynamics. To understand the root causes of why some implicit prices for local public goods are rising and others are falling, we need to think through what are likely income elasticities and what has been the evolution of the prices of complements and substitutes for the good in question. Consider complementarities of local public goods. As air pollution declines in major cities, people will be willing to pay more for safe streets because they will want to spend more time outside. In nice climate cities where people want to be outside, people will value more a given reduction in air pollution or crime. These examples highlight that the marginal valuation of a local public good is likely to be a function of the consumption of that good and the value of complementary local public goods. A testable implication would be that as crime declined in urban areas in

the 1990s that this increased the valuation of pollution reductions and the valuation of temperate climate.

Estimated hedonic valuations will change over time as the supply of market substitutes for these non-market public goods changes. During the 20th century, air conditioners fell sharply in price and this market good helped to offset exposure to high humidity and thus supplies comfort even in a potentially unpleasant place like a Houston summer. As the supply of market substitutes shifts, this can change the hedonic gradient. For every non-market local public good, there are market substitutes. Good doctors and drugs can offset pollution exposure. Private security forces can offset the danger of living in a high crime area. All else equal, a city with high victimization rates will feature lower home prices. Now suppose that a bodyguard service for a relatively low fee will protect millionaires such that they are never robbed. A hedonic researcher who regressed for a set of millionaires across-cities, the price of their condo on crime before and after the bodyguard service would see the implicit price of victimization fall. A false inference would be that millionaires care less about crime now than in the past. The real data generating process is that the millionaires can pay an explicit market price for the bodyguard. Having a bodyguard shields the millionaire from victimization risk and even a risk averse millionaire would now need a smaller compensating differential to live in a high crime city. Thus, the marginal millionaire would simply need a price discount in a dangerous city that allows him to pay his bodyguard. When market goods can substitute perfectly for local public goods, observed hedonic prices will not recover marginal preference valuations. Instead, these implicit prices will reflect the marginal cost of market substitutes to offset the exposure.

7. Econometric Challenges in Estimating Cross-City Hedonic Regressions

A. Endogenous Environmental Quality

The previous section documented that due to changes in demand the implicit price of a non-changing local public good such as climate can change over time. Regulation induced shifts in the supply of local public goods, think of the Clean Air Act or successful urban policing, will also change the estimated hedonic price function. This section examines in detail how hedonic valuations are likely to be affected by shocks to local public goods.

Consider urban particulate levels. Many leading cross-city hedonic studies such as Blomquist, Berger and Hoen (1988), Gyourko and Tracy Roback (1982) and see the meta-analysis by Smith and Hwang (1995), document that cities with higher particulate levels have lower home prices. The cross-city hedonic literature has not devoted enough attention to what is the underlying source of local public goods. In the case of urban particulates, they are mainly produced by a higher scale of economic activity in local factories and electric utility plants. In this case, pollution will be pro-cyclical. When the local economy is booming, particulates will be high and during recessions particulates will be low (see Chay and Greenstone 2003, Kahn 1997, 1999). Ignoring all other local public goods, the typical cross-city environmental studies runs a regression of:

$$\text{Log(home price)} = a + a1*\text{Particulates} + U \qquad (7)$$

My point is that the Gauss-Markov assumptions require that E(U|Particulates) equals zero for an OLS regression of this form to recover the true compensating

differential. But, if particulates and home prices are high when the business cycle is booming then the error term and particulates will be positively correlated. Since we expect that a1 is less than zero, a OLS regression of log(home price) on particulates is biased toward zero. Cross-city hedonic studies are likely to underestimate the negative impact of air pollution on home prices because in the cross-section high air pollution partially represents a booming local economy. Just think of Pittsburgh at its peak in the 1950s and 1960s. Yes, particulate levels were high but the booming economy provided jobs for relatively low skilled workers and this propped up housing demand. In an extreme case, the cross-sectional hedonic researcher will observe high home prices in high air pollution areas and falsely conclude that air pollution is an amenity!

While air pollution is often an unintended byproduct of production and driving, other environmental goods are often a conscious decision by local governments to provide services. In this case, environmental quality may be high because taxes are high. For example, suppose that a city has excellent garbage service but its residents pay very high taxes due to public sector unionization. In this case, if a hedonic researcher had access to a measure of the quality of garbage collection but no information on taxes, then the hedonic price estimate of the quality garbage may be biased down because it is proxying for higher tax bill that is bundled with the garbage services. A similar issue arises with respect to other local amenities such as proximity to open space.

B. Geography and Measurement Error in Local Public Goods

Several of the best known cross-city quality of life studies such as Blomquist, Berger and Hoehn (1988) and Gyourko and Tracy (1991) have ambitiously included a

large number of city attributes including climate, air pollution, crime and schools. While these last three are important local public goods a tricky econometric issue of measurement error arises. These researchers must resort to assuming that each person in a city is exposed to the *average* level of local public goods in the city. In a heterogeneous city, this introduces measure error. This measurement error issue arises because confidentiality concerns in public use data sets such as the Census provide very coarse indicators of a person's geographical location. The typical cross-city hedonic researcher knows that a person lives in Chicago but does not know if this person lives in Hyde Park or Evanston. Within metropolitan area variation in community level crime may be much larger than cross-metropolitan area variation in average crime. Within a metropolitan area, the population Tiebout sorts into communities. Thus, the average crime level in a Metropolitan area is a noisy proxy for the crime level of the community the household actually chooses. Unlike crime or air pollution, within metropolitan area variation in climate exposure is likely to be quite small.

Gyourko and Tracy (1991) recognized this problem and included only data points from center cities using their 1980 Census sample. But, in the year 2000 the average meteropolitan area resident lives in the suburbs. Thus, in recent years a center city analysis would throw out the majority of the sample in its attempt to rank city quality of life. This does raise the interesting issue of when does the researcher care about the entire MSA versus the specific center city's quality of life. An urban mayor would be more interested in the latter while a corporation considering where to locate would be more interested in the former.

For researchers focusing on cross-city hedonic research, what can be done to improve data quality? The Census now allows researchers to apply to various Data Centers around the United States. Within such data centers, researchers can use confidential census files that provide more detailed geography such as the census tract for each individual household. If a researcher could access such geocoded data, then he could explicitly control for local school quality and local crime levels (see Bayer, McMillan and Rueben 2004) and provide more precise estimates of the hedonic prices of local public goods such as air pollution and climate.

Geographic Information Software has greatly improved our ability to do sophisticated data merges such as superimposing the location of air pollution monitoring stations with respect to the location of a household's census tract. I am optimistic that the amount of measurement error in future cross-city hedonic studies will decline and this will yield more valid estimates of the underlying true hedonic gradient. Classical measurement error in crime and school quality and proximity to Superfund sites leads the cross-city researcher to underestimate the capitalization of these goods especially relative to non-market goods such as climate that do not vary much within city.

Researchers have focused on what they are able to measure. The best data exists on climate and air pollution. Due to the absence of data, other important measures of environmental quality such as water quality and exposures to toxics have been under-researched. Air quality is converging across cities across the United States. While this is good news for people in past smoggy areas, this convergence means that hedonic researchers will not have the variation to measure compensating differentials.

While air quality may diminish as a capitalized cross-city local public bad, the results in Table One and Two show that climate capitalization is growing over time. In addition, other environmental threats pop up over time. The events of September 11th 2001 awakened people to the threat of domestic terrorism. While it is obvious that cities that face a higher risk of a terrorist attack would feature compensating differentials for this "environmental" risk, how can this risk be quantified? Are terrorist risks actuarially priced? Do hedonic housing markets suggest that the market has "over-reacted" to fear of terrorism? Early hedonic studies claimed that earthquake risk was actuarially priced in California (Brookshire et. al. 1982). Risk perception and risk capitalization would seem to be a natural research area for the cross-city quality of life literature which would nicely dovetail with the mushrooming interest in behavioral economics. In his 2002 Nobel Prize speech, Kahneman (2003) emphasizes how prospect theory hypothesizes that people value avoiding losses more than they value gains. If researchers could identify negative and positive environmental shocks then we could test this hypothesis using hedonic methods.

This section raises the issue of what environmental attributes should be priced using cross-city versus within city hedonic methods? Clearly, climate valuation should be measured using inter-city data but what about air quality or proximity to hazardous waste sites? Intuitively, very localized local public goods should be priced using within city variation while local public goods whose quality is uniform within a city and climate can only be priced using cross-city data. There are certain intermediate cases such as proximity to the coast. In Los Angeles, communities closer to the beach are cooler and have greater beach access. Within California, counties on the ocean again feature lower

temperature and have greater beach access than inland counties. Ideally, hedonic research would measure such effects using both types of data variation. Philosophical issues arise. Post September 11th 2001 if New York City residents now fear a dirty bomb, does this environmental hazard affect home prices in the Westchester suburbs or just in downtown Manhattan densely populated areas? If only downtown Manhattan faces the environmental risk from a dirty bomb, then intra-city hedonics should be used to price such newly discovered risks.

C. Self Selection and Inference Based on Cross-Sectional Cross-City Hedonics

The cross-city hedonic literature seeks to estimate compensating differentials for living in low quality of life cities. The hedonic value of life literature seeks to estimate the compensating differential (i.e higher wage) for working in industries with higher fatality risk (see Viscusi 1993). It is no accident that Sherwin Rosen started both of these literatures (Thaler and Rosen 1976, Rosen 1979). A notable difference between these two literatures is that labor econometricians have made more progress in identifying the implicit assumptions that are required to interpret cross-sectional hedonic regressions as recovering interesting economic parameters. In an important 1992 paper, Hwang, Reed and Hubbard argued that the value of life literature is likely to under-estimate the value of life because high skilled workers (on unobservable to the econometrician dimensions such as IQ) choose not to enter risk industries. From the wages of steel workers, it is almost impossible to infer what wage would attract Don Trump to give up real estate development for him to be a steel worker. The wages of steel workers must represent a lower bound on the compensating differential he would require.

Log wage = a + b1*industry risk + U (6)

Does a similar issue arise in cross-city hedonic regressions? While in the past urban economists argued that bigger cities have lower amenities due to congestion and pollution effects (Tolley 1974), today many scholars argue that bigger cities may have a greater variety of amenities and cultural opportunities. While New York City is congested, its amenities are unique and attract tourists from around the world. In cosmopolitan cities such as New York, superstars of all fields ranging from Don Trump in real estate, to Derek Jeter in baseball to Jeff Sachs in economics have all chosen to work there. A naïve cross-city hedonic researcher would observe these stars living in New York City earning high wages *relative* to observationally identical people in Tulsa and conclude based on the wage regression that New York City's quality of life must be worse than Tulsa. Clearly, the problem with this inference is the "apples to oranges" comparison.[3] Future cross-city hedonic wage research should attempt to tackle the issue of self-selection of superstars into certain major cities and how this affects inference about amenity valuation from hedonic regression. An implicit but untested assumption is that each city contains a representative sample of the nation's population. One way to test this assumption would

[3] Would there be less concern about sorting on unobservables for the hedonic home price regressions? This hinges on how developers choose what attributes to bundle into homes. Consider swimming pools. In typical Census data, whether a home has a swimming pool is unobserved. If homes in warmer winter locations are more likely to have a swimming pool, the hedonic researcher will over-estimate the value of winter temperature because this will be positively correlated with the error term. This example highlights how housing attributes hinge on complementarities in consumer preferences. In this case, consumers value a pool more in a warmer location and developers respond to this demand by bundling such attributes into the homes and these attributes are then capitalized into the sales price.

be to use the National Longitudinal Survey of Youth that has a AFQT score (see Neal and Johnson 1995) and study population sorting with respect to this IQ proxy.

8. Hedonic Estimation Using a "Quasi-Experimental" Discontinuity Estimator

The econometric techniques used in the cross-city hedonic literature have been relatively simple. Researchers typically run multivariate OLS regressions with a correction for the standard errors to take into account clustering by metropolitan area (Gyourko and Tracy 1991, Moulton 1990). As discussed above, the implicit identifying assumption in these models is that the unobserved attributes of workers and homes are uncorrelated with the observed attributes. As is well known, when researchers have access to panel data they can estimate a richer specification that controls for greater population heterogeneity such as to include person or home specific fixed effects. Unfortunately, standard data sets used in cross-city hedonic research such as the Census of Population and Housing, the American Housing Survey and the Current Population Survey are not panels. One solution to this problem is to aggregate the data and to work with county level panel data.

In a prominent recent cross-city hedonic paper, Chay and Greenstone (2003) use county level panel data to measure what is the implicit price of exposure to total suspended particulates (TSP). Exposure to particulates raises morbidity and mortality risk (Chay and Greenstone 2003b). Ignoring all other controls, a simple OLS regression of home prices on TSP at time t would take the form:

$$Price_{jt} = a + b^* TSP_{jt} + U_{jt} \qquad (8)$$

Their first step in their research is to first difference their data by county to calculate between 1980 and 1990 the change in price and the change in tsp levels by county.

$$\Delta Price_{jt} = b^* \Delta TSP_{jt} + U_{jt} \qquad (9)$$

Rather than simply running OLS on this first differenced regression, they seek an instrumental variable for ΔTSP_{jt}. Intuitively, they seek a variable that exogenously shifts a county's particulate change but that is unrelated to home prices. Ingeniously, they point out that the Clean Air Act's rules for assigning counties to different levels of regulation offers such an instrument. The Clean Air Act partitions counties into more stringent "non-attainment" status and less stringent "attainment" status based on each county's particulate level in the early 1970s. The Clean Air Act set an explicit rule that counties whose annual geometric mean was greater than 75 micrograms per-cubic meter were assigned to "non-attainment" while counties whose particulates levels were below this threshold were assigned to low regulation "attainment status". Chay and Greenstone (2003) compare home price growth in counties just below this cutoff to counties just above this cutoff. Intuitively, these two groups of counties were quite comparable and then for the counties just above the cutoff they experienced more severe regulation that reduced their particulate levels relative to the "control group" of attainment counties. This quasi-experimental design is a significant advance over the more traditional cross-sectional hedonics.

This regression approach is called a discontinuity estimator because the instrumental variable, county regulatory status, jumps in a discontinuous fashion with respect to the county's TSP level in the early 1970s. Using this instrumental variable

approach, Chay and Greenstone report a much larger hedonic coefficient estimate than the earlier literature.

Two caveats should be noted with regards to their cross-city design. County data is highly aggregated. First, if the household level hedonic is highly non-linear, then an aggregate county level hedonic may recover a very different relationship. Second, over time counties grow at different rates and the marginal entrant may be very different than the average incumbent. Consider a sprawling county where poor people are moving in and locating at its fringe. Average home prices would fall over time for this county because of growth inducing a composition effect. Other sprawl issues arise. Suppose that anticipating future growth and worried that it will lead to congestion and reduce open space at the fringe, a county adopts a Urban Growth Boundary like Portland's. Suppose in the Chay and Greenstone study that 99% of "non-attainment" highly regulated counties are in metropolitan areas that do have suburban growth controls and 1% of regulated counties do not. In this case, I would predict a larger estimate of b, then if there were no growth controls for the metropolitan area. Why? Growth controls make the supply curve of housing more inelastic (Katz and Rosen 1981, Glaeser, Gyourko and Saks 2003). When the supply of housing is highly inelastic because land is fixed due to the land control regulation, increases in demand will translate into larger increases in price and very small quantity changes.

Chay and Greenstone's study contributes to a tiny but influential literature on hedonic estimates based on discontinuity estimators. Black (1999) used within city variation in the Boston area to measure school quality capitalization into local home prices. She identified school boundaries between "good" and "bad" local schools. If your

home is on the "good" side of the boundary, your child can attend the good local school (measured by test scores), while if your home is 100 feet away but on the bad side of the boundary, your child attends the low quality school. By solely comparing differences in home prices for these nearby homes, Black controls for local neighborhood effects and simply prices the capitalization of the differential school quality. Cross-boundary differences in average home prices divided by cross-boundary differences in average school quality provides an estimate of hedonic price per unit of school quality. An ongoing challenge for environmental hedonic researchers is to design empirical strategies that are as "clean" as Black's (1999). Unlike many environmental attributes that literally spillover political boundaries, political boundaries do divide access to good schools and mediocre schools.

One potential criticism of both Black's (1999) and Chay and Greenstone's (2003) hedonic discontinuity estimators is that they over-estimate the effect of the attribute in question because the jump in the local public goods caused by the discontinuity leads to population migration. To see why this might effect hedonic estimates, consider the simplest example of Black's econometric design:

Home price = housing structure controls + b1*1(good school district) + U (10)

Where 1() is a dummy variable that equals one if the home is in the good school district and equals zero if it is located in the bad school district. Suppose that parents choose where to live and that parents who like good schools also like fancy indoor swimming pools. This unobserved housing attribute will be positively correlated with the good school district dummy and OLS estimates of this equation will over-estimate "b1".

My point is that the discontinuity, the jump in school quality at the border, can induce population sorting such that the rich live on one side of the boundary and upgrade their homes in ways that the econometrician does not observe but that are observed and capitalized into real estate prices.

A similar concern can be raised with Chay and Greenstone's (2003) study. In counties where particulate levels are declining due to successful Clean Air Act regulation, these counties may now self select high skilled amenity seekers. As discussed in the work of Florida (2003) and Glaeser, Kolko and Saiz (2001), an emergent property of attracting these skilled culture makers is improved local restaurants, and improved culture. In Kahn (2000), I documented that between 1980 and 1999, the number of days per year that the Los Angeles greater area exceeded the national one hour ozone smog standard has fallen from 167 to 39. The greatest reductions in ozone smog have taken place in the distant Los Angeles suburbs of Riverside and San Bernardino. I documented that as ozone smog declined in these Los Angeles suburbs, amenity seekers, namely college graduates and senior citizens, were much more likely to migrate to these areas than in the past.

If cities experiencing improved air quality import high skilled people who help to improve the local culture and the variety of restaurants, then the Chay and Greenstone empirical strategy will yield an upper bound on the capitalization of particulates into home prices because *all else is not equal*. Local amenity shocks are likely to trigger multiplier effects on urban quality of life. Ideally Chay and Greenstone (2003) would measure holding population demographics constant, how are home prices in a county affected by an exogenous increase in air quality. But, equilibrium sorting and migration

responses guarantee that population demographics will change as the amenity improvement takes place.

To conclude this section, the regression discontinuity approach is an important recent advance in applied econometrics for recovering causal effects. The recent excitement about both Black's (1999) and Chay and Greenstone's (2003) hedonic projects shows that the general economics profession can get quite excited about hedonic research when a convincing "quasi-experimental" design can be constructed.

9. Migration and Cross-City Hedonic Gradients

The previous section highlighted the importance of migration responses in the face of utility arbitrage opportunities. A prime example of how changes in local public goods induced migration is changes in New York City's Harlem as crime has fallen. The New York Times has run several stories about yuppies moving into the community bidding up the price of brownstones and unintentionally displacing poorer long time renters from their home community. This example highlights that migration determines the incidence of local public goods improvements.

Three percent of the people in the United States move across states each year. This group has an incentive to compare their expected earnings net of rents and quality of life in every possible destination. Any shock to local public goods such as September 11th 2001 impact on perceived quality of life in New York City or declining crime in the 1990s in New York City or declining Smog in Los Angeles will trigger cross-city migration until the marginal migrant is again indifferent across cities.

If cross-city migration was impossible, perhaps due to transportation costs, then there would be no information in comparing wages or real estate prices across cities. Even if Boston was nicer than Detroit, it could be an equilibrium if Boston real estate prices were higher than Detroit's because nobody could move. Thus, migration plays a key role in guaranteeing that cross-city prices are informative. While the hedonic literature pretends that migration is costless, the truth is that the population, especially the young and educated, is mobile but migration is financially and in terms of social capital lost is costly.

Using cross-state data Cragg and Kahn (1997) estimated state locational choice as a function of each state's climate, quality adjusted rents, wages, and unemployment risk. To impute rents and wages in every state that a migrant might choose, we estimated hedonic regressions. As discussed above, the key implicit assumption in such an analysis is that the wages for the set of people who "look like you" on observables in a state you are considering choosing can be used to impute what your earnings would be if you chose that state. Don Trump would pose a problem for such a migration model because he is unlikely to be able to impute what his earnings from living in Kansas would be from the set of Kansan real estate developers who are already working there.

All households face a "two stage" locational issue that the cross-city hedonic literature ignores by implicitly assuming that local public goods are homogenous within cities. Facing the hedonic wage and land gradients, households choose which metropolitan area to live in. Then, conditional on having chosen a metro area, households then take the within metro area hedonic real estate gradient as given and choose their utility maximizing community and home. Within Chicago or Boston, there is

great variation in local schools, air pollution, crime and proximity to noxious waste facilities (Kolhase 1991, DiPasquale and Kahn 1999).

A concrete example might focus attention on the core issue. In a set of recent papers, Sieg, Smith, Benzhaf and Walsh (2003, 2004) have examined how differential improvements within Los Angeles in local smog levels affects the locational choices of households. Intuitively, smog reductions far away from the Pacific Ocean within Los Angeles transform previously low amenity areas into much nicer areas. Middle class and richer people will now consider living in such areas. Air quality in Los Angeles has improved because of successful Clean Air Act regulation. Sieg et. al. seek to study how the Clean Air Act has affected population sorting within Los Angeles. They demonstrate that richer people, think Barbara Streisand, who own homes in the always low smog areas near the beach are actually losers from the Clean Air Act because this regulation increases the supply of "nice areas" within Los Angeles making the scarcity rent on the Streisand estate decline. The Sieg paper does not address the cross-city migration issue. As Los Angeles smog improves will people in Denver and Portland now move there? If such people choose to move to Los Angeles, and Kahn (2000) documents that Los Angeles's suburban counties of Riverside and San Bernardino have been sprawling as smog has fallen sharply there, then a general equilibrium analysis of the Clean Air Act should incorporate the cross-city migration flows it induces. The Clean Air Act will have little impact on a low smog city such as Tulsa but it will increase quality of life in Los Angeles and this in turn triggers migration from Tulsa to Los Angeles.

Why does this matter? Determining whether improved city environmental quality triggers migration is crucial for estimating the incidence of environmental

regulation. Billions of dollars have been spent on environmental regulation since the 1970s as the Environmental Protection Agency (EPA) has regulated many pieces of the environment. In places where the environment is improving, are home prices rising? If this is the case, then regulation could actually be regressive. Renters would now pay more in rents in cities such as Los Angeles and their tax dollars funded the EPA for the regulation that lead to the pollution reduction. If few people from outside the city are moving to the city as amenity improvements take place, it is less likely that home prices will soar in the improved areas.

This section has focused on native migration without mentioning foreign immigration. As shown by Saiz (2003), given that housing supply in cities is inelastic in the short run, unexpected immigrant shocks can drive up city home and rental prices. If coastal cities are more likely to experience these shocks, then the hedonic researcher is likely to over-estimate how much households value coastal amenities.

10. Cross-City Hedonic Analysis Outside of the U.S

Too much empirical research measuring compensating differentials has focused on the United States. Fortunately, in recent years innovative research is examining data from other nations such as Russia and Brazil.[4] Berger, Blomquist, and Sabirianova (2002) estimate cross-city hedonic regressions using micro data from Russia. Russia's enormous size means that many different cities that have different bundles of climate, pollution, and crime exist. How big a compensating differential does it take for people to remain in cold Siberia? In ex-communist countries, how many years did it take after the

[4] Timmins (2003) estimates an equilibrium model of locational choice within Brazil.

establishment of competitive housing markets for prices to adjust to reflect true compensating differentials across cities (Bertaud and Reanud 1997)?

Clearly, Eastern Europe offers a host of interesting experiments for hedonic researchers. The death of communism has greened Eastern Europe's cities. The transformation of these urban economies has sharply reduced air pollution and hence increased quality of life (Kahn 2003).

The recent European Union expansion and labor market integration offers another interesting test of hedonic capitalization. Maddison and Bigano (2003) use Italian data and hedonic methods to document the capitalization of climate into Italian real estate prices. As EU integration continues, will a European "law of one price" emerge? Or, due to cultural and language barriers, will arbitrage opportunities persist such that lucky migrants can enjoy improved amenities without sacrificing lower wages and higher rents?

11. Conclusion

After 25 years of active research, the cross-city hedonic quality of life literature continues to evolve and pursue new hypotheses. However, it must be acknowledged that in recent years the vast majority of hedonic papers have appeared in field journals rather than in top general journals. The economics profession has not lost interest in valuing non-market public goods using revealed preference techniques. Instead, researchers have retreated. Very few hedonic researchers have attempted to implement the "second stage" of the Rosen two step to recover deep demand parameters such as the willingness to pay for environmental improvements. Without such estimates, one cannot conduct credible policy counter-factuals or conduct welfare analysis. As noted by Rosen (1974), the first

stage hedonic is a reduced form regression whose coefficients only represent a mixture of "deep" structural producer and consumer attributes. Recent work by Eskeland, Heckman and Nesheim (2004) and Bajari and Benkhard (2004) suggests that the non-linear hedonic gradient can be used to identify willingness to pay for local public goods. Environmental applications building on this theoretical work would be quite valuable.

Hedonic researchers tend to pragmatic and price what they can get their hands on to include as another explanatory variable. Given the importance of climate as an amenity and as a health input, I believe it is important that cross-city hedonics continue to price this key non-market public good. Given cross-city convergence in air pollution levels, I am not convinced that it is important or interesting to estimate cross-sectional air pollution capitalization regressions in the year 2004. Researchers could certainly test hypotheses for air pollution capitalization in developing countries where there is much more cross-sectional variation.

This chapter has tried to suggest some future avenues of research on relatively unexplored topics. For example, an unintended consequence of the War on Terror is that cross-city hedonic research could be revitalized by focusing on risk perception and capitalization effects similar to the earthquake and natural disaster risk literature (Brookshire 1982, Hallstrom and Smith 2003). A second fruitful line of domestic research could focus on the costs of sprawl. While the popular press has claimed that ongoing suburbanization negatively impacts quality of life, does it? Hedonics is a natural tool for testing whether growing cities experience declining quality of life (see Kahn 2001).

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Table 1: Trends in Climate Pricing Based on Repeat Hedonic House Price Regressions

	1970	1980	1990	1999
July temperature	-108.850	-195.560	-407.990	-309.305
	(16.119)	(27.480)	(64.918)	(62.579)
January temperature	8.132	71.529	136.690	67.129
	(7.644)	(14.588)	(23.994)	(20.291)
Annual rainfall	-9.451	-60.149	-58.859	-43.596
	(8.279)	(8.658)	(18.005)	(22.672)
Pseudo R^2	0.25	0.244	0.185	0.177
Observations	43,173	42,019	49,506	14,212

Note: Results are from a censored median regression (Powell 1984). The dependent variable is the level of annualized home prices in 1990 dollars. Standard errors clustered on the metropolitan area are in parentheses. The samples, from the censuses in 1970-1990 and the American Housing Survey in 1999, were restricted to owners. Additional covariates include the age of the unit, the number of rooms, and a dummy variable indicating whether the unit is a single detached home.

Table 2: Trends in Climate Pricing Based on Repeat Hedonic Hourly Wage Regressions

	1970	1980	1990
July temperature	-0.104	-0.087	-0.106
	(0.019)	(0.020)	(0.022)
January temperature	-0.019	-0.029	-0.009
	(0.011)	(0.013)	(0.008)
Annual rainfall	-0.018	-0.015	-0.007
	(0.012)	(0.009)	(0.008)
Pseudo R^2	0.115	0.105	0.130
Observations	50,000	50,000	50,000

Note: Results are from a censored median regression (Powell 1984). The dependent variable is the level of men's hourly wages in 1990 dollars. 50,000 observations were randomly drawn from each census. The samples were restricted to full-time men age 25-60. The top and bottom one percent of wages were trimmed. Standard errors clustered on the metropolitan area are in parentheses. Additional covariates include age, age squared, and dummy variables indicating educational level (less than high school, high school, and college) and non-white.